(12) UK Patent Application (19) GB (11) 2 370 769 (13) A

(43) Date of A Publication 10.07.2002

(21) Application No 0123146.3

(22) Date of Filing 26.09.2001

(30) Priority Data
(31) 0100530 (32) 09.01.2001 (33) GB

(71) Applicant(s)
Kidde Plc
(Incorporated in the United Kingdom)
Mathisen Way, Colnbrook, SLOUGH, Berkshire, SL3 0HB, United Kingdom

(72) Inventor(s)
Robert George Dunster

(74) Agent and/or Address for Service
Mathisen & Macara
The Coach House, 6-8 Swakeleys Road, Ickenham, UXBRIDGE, UB10 8BZ, United Kingdom

(51) INT CL⁷
A62C 35/02

(52) UK CL (Edition T)
A5A A20X4 A6

(56) Documents Cited
EP 0784998 A2
US 4634050 A
US 4186772 A
WO 96/34660 A1
US 4397422 A

(58) Field of Search
UK CL (Edition T) A5A
INT CL⁷ A62C 5/00 35/02 39/00
Online: WPI, EPODOC, JAPIO

(54) Abstract Title
Fire and explosion suppression

(57) A fire and explosion suppression system comprises a source (5) of high pressure water which is fed to a misting nozzle (13) or other water mist generating means at one input of a mixing unit (6), and a source (14) of high pressure inert gas, such as nitrogen, which is fed along a pipe (20) to another input of the mixing unit (6). Inside the mixing unit (6), water mist, in the form of an atomised mist of very small droplet size is mixed with the pressurised gas and exits the mixing unit (6) at high pressure and high velocity along a pipe (22) and is thence discharged through spreaders (26,28). Separation of the mist production from the actual discharge of the mist, and the entraining and transporting of the mist between these two stages at high pressure and high velocity, produces an output mist of very small droplet size which is carried by the entraining and transporting high pressure gas into the area to be protected, enabling a total flooding capability. The misting nozzle (13) may be replaced by an eductor (13A, Fig 2) which uses a venturi effect.

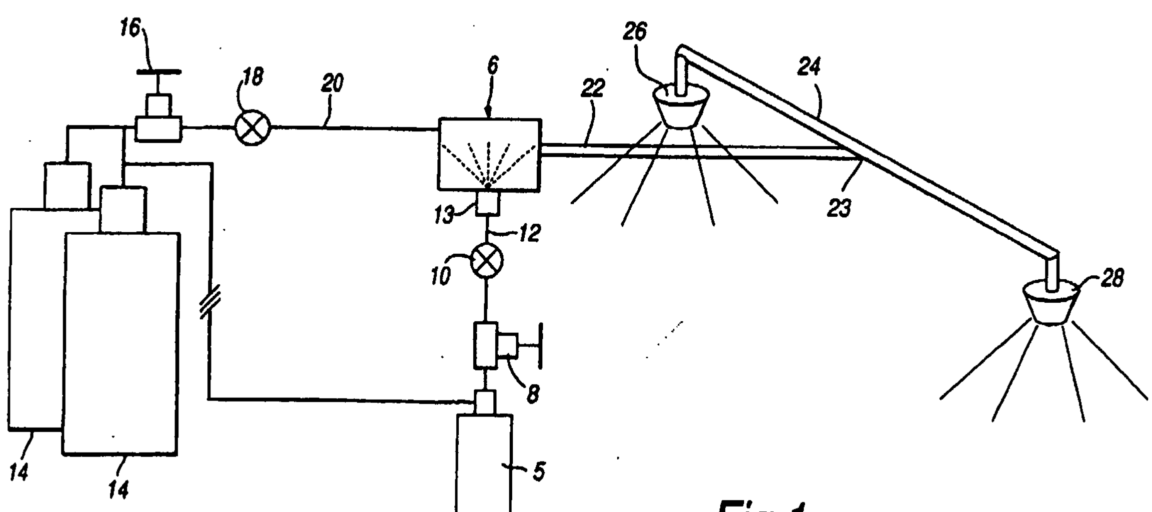

Fig.1

GB 2 370 769 A

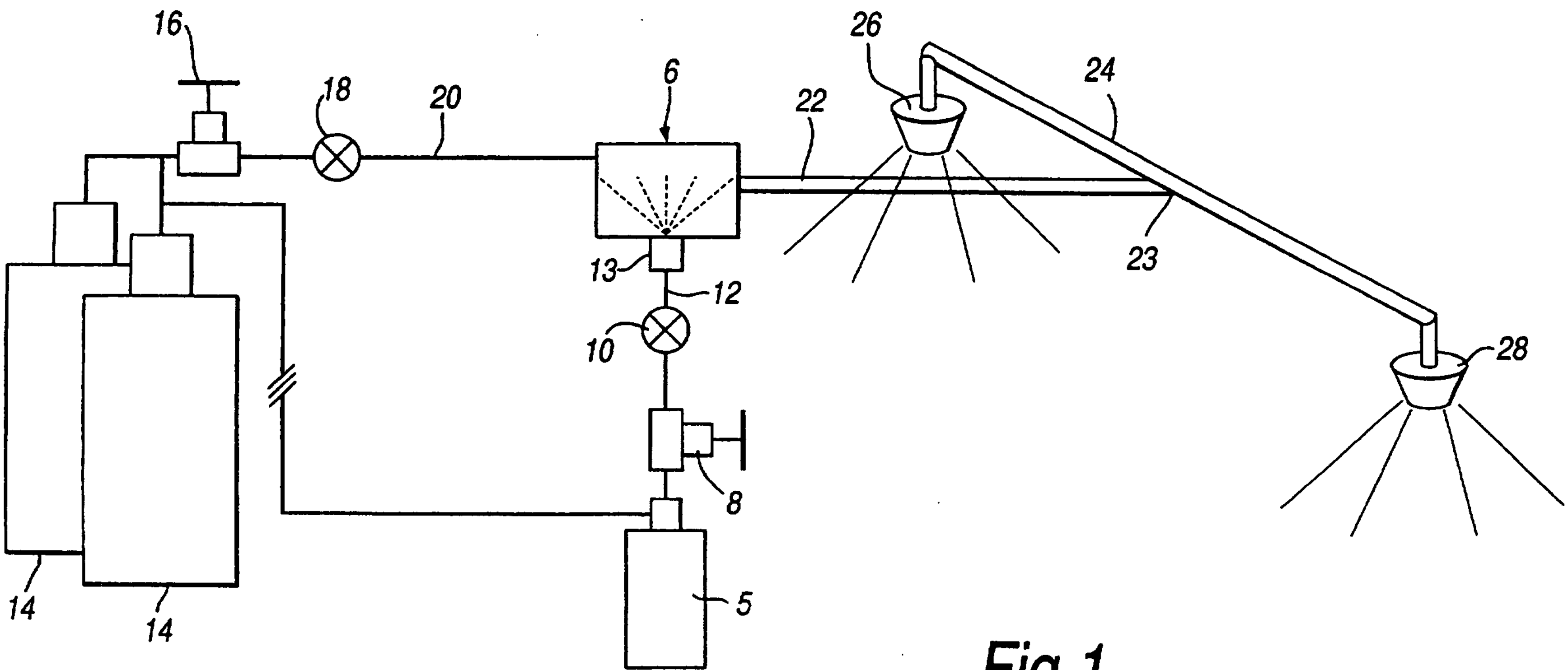

Fig.1

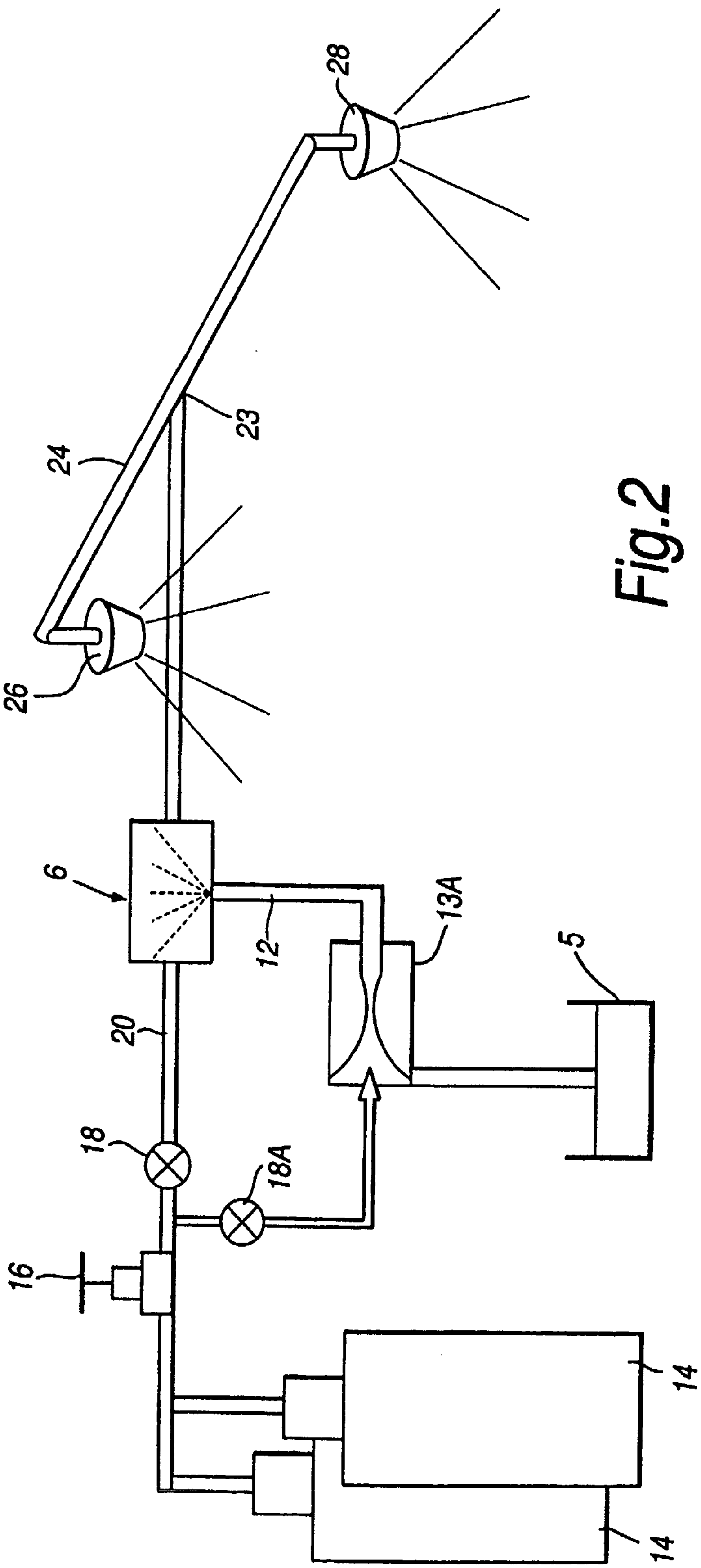

Fig.2

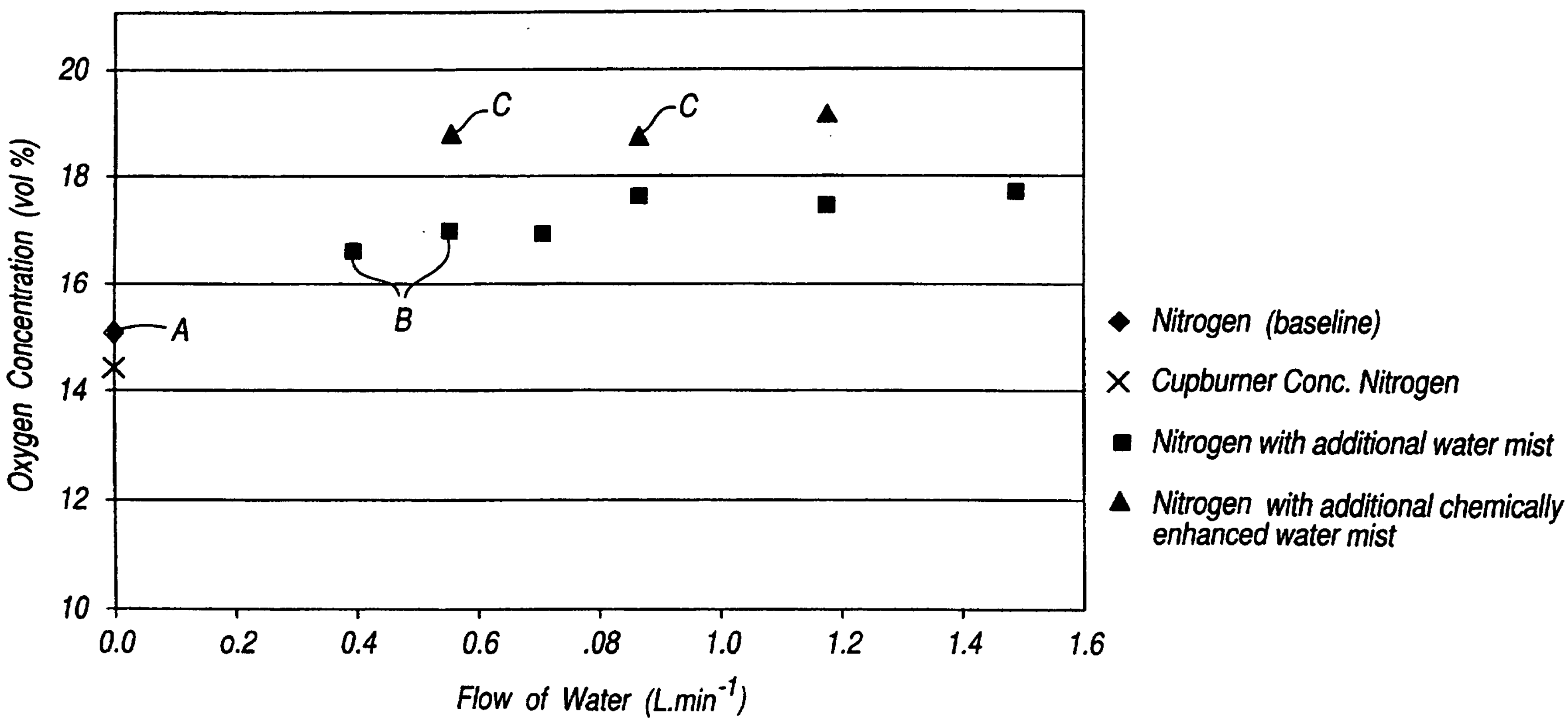
Oxygen Concentration (vol %)
20
18
16
14
12
10
A
B
C
C
0.0
0.2
0.4
0.6
.08
1.0
1.2
1.4
1.6
Flow of Water (L.min-1)
Nitrogen (baseline)
Cupburner Conc. Nitrogen
Nitrogen with additional water mist
Nitrogen with additional chemically enhanced water mist

Fig.3

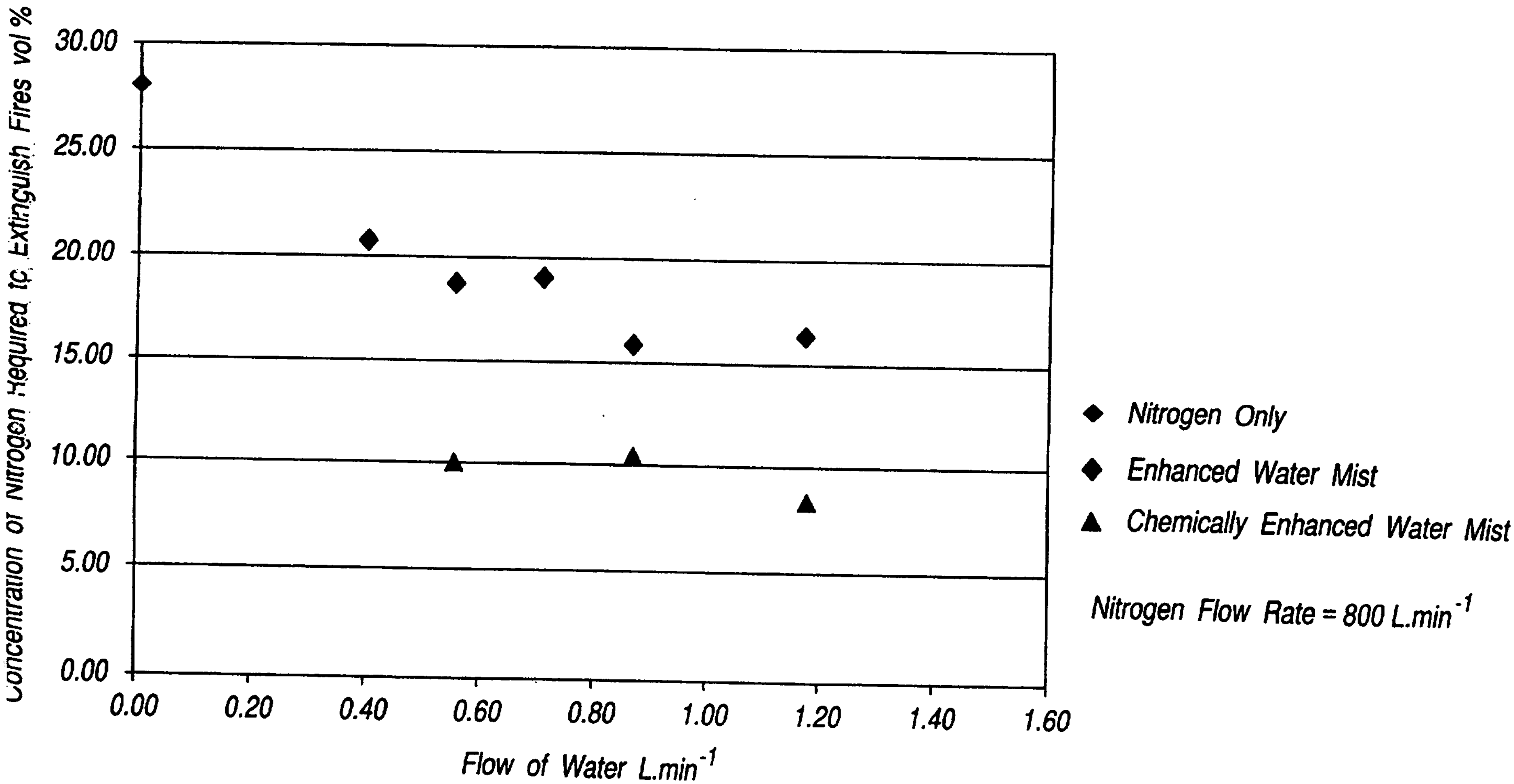
Concentration of Nitrogen Required to Extinguish Fires vol %
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
Flow of Water L.min-1
Nitrogen Only
Enhanced Water Mist
Chemically Enhanced Water Mist
Nitrogen Flow Rate = 800 L.min-1

Fig.4

FIRE AND EXPLOSION SUPPRESSION

The invention relates to fire and explosion suppression. Embodiments of the invention, to be described below by way of example only, use water mist as the suppression agent.

According to the invention, there is provided a fire and explosion suppression system, comprising a source of water and a source of pressurised inert gas, water mist producing means connected to receive the water to produce a mist therefrom, mixing means for mixing the already-produced mist into a flow of the pressurised inert gas from the source thereof to produce a two-phase mixture comprising a suspension of droplets of the water mist in the pressurised inert gas, and transporting means for transporting the two-phase mixture to separate discharge means.

According to the invention, there is also provided apparatus for producing a mist from a liquid, comprising an eductor.

According to the invention, there is further provided a fire and explosion suppression method, comprising the steps of producing a water mist from pressurised water, mixing the already-produced mist into a flow of pressurised inert gas to produce a two-phase mixture comprising a suspension of droplets of the water mist in the pressurised inert gas, and transporting the two-phase mixture for separate discharge.

According to the invention, there is yet further provided a method of producing a mist from a liquid, in which a gas is fed under pressure to an eductor to draw the liquid into the eductor to produce the mist.

Fire and explosion suppression systems and methods according to the invention, employing water mist, will now be described, by way of example only, with reference to

the accompanying diagrammatic drawings in which:

Figure 1 is a schematic diagram of one of the systems;

Figure 2 shows a modification to the system of Figure 1; and

Figures 3 and 4 are graphs for explaining operation of the systems.

Referring to Figure 1, the system has a vessel 5 storing water. The vessel 5 is connected to an input of a mixing unit 6 via a pressure regulator 8, a flow regulator 10 and a pipe 12. At the input to the mixing unit 6, the pipe 12 feeds the water to a misting nozzle 13 or other water mist generating means (for example, a simple orifice or restriction hole across which a pressure differential is maintained).

The system also includes a vessel or vessels 14 storing an inert gas such as nitrogen. Vessels 14 have an outlet connected via a pressure regulator 16, a flow regulator 18 and a pipe 20 to another input of the mixing unit 6. The mixing unit 6 has an outlet pipe 22 which connects with a distribution pipe 24 terminating in spreader or distribution heads 26,28.

In use, water from the vessel 5 and gas from the vessels 14 are fed under high pressure to the mixing unit 6 through the pressure regulators 8 and 16 and through the flow

regulators 10 and 18 which regulate the pressure and flow rates.

The water in the vessel 5 may be pressurised by a separate pressure source not shown. Instead, though, it could be pressurised by the gas within vessels 14, via an interconnection 30.

The nozzle 13 comprises any suitable form of nozzle for atomising the water to produce a water mist. Examples of suitable misting nozzles include single or multi-orifice plates, single or multi-orifice phase direct impingement nozzles, spiral insert nozzles and rotating disc nozzles. In principle, any standard water mist type nozzle can be used.

In the mixing chamber 6, the water mist produced by the misting nozzle 13 is effectively added to the inert gas. The resultant two-phase mixture (that is, water mist droplets carried by the inert gas) exits the mixing chamber along the outlet pipe 22 and is carried at high velocity to a T-junction 23, and thence along the distribution pipe 24 to exit from the spreaders 26,28 into the volume to be protected (that is, the room, enclosure or other space where a fire or explosion is to be suppressed).

In the system of Figure 2, the misting nozzle 13 is replaced by an eductor 13A which uses a venturi effect. A subsidiary flow of the high pressure gas from the vessels 14 passes via a flow regulator 18A into the eductor 13A where the venturi effect causes a low pressure area to be formed. This low pressure area draws water from the vessel 5 via the flow

regulator 10, the water being at low pressure or unpressurised. A water mist is formed at the point of intersection between the two fluids. This mist exits along the pipe 12 into the mixing chamber 6 where it is added to the main flow of inert gas arriving via flow regulator 18 and pipe 20 in the system in the manner described with reference to Figure 1. The resultant two-phase mixture (water mist droplets carried by the inert gas) exits along pipe 22 as described with reference to Figure 1.

In each case (Figures 1 and 2), where the water mist and the very high flow of inert gas join, a process known as air blast or aerodynamic atomisation takes place. The water droplets interact with the fast flow of inert gas, and rapidly form into flattened sheets which break up into a cloud of minute droplets. The droplet size in the cloud depends on the relative flow rates between the water and the inert gas. The preferable median droplet size is between 5 and 60 micrometres.

It will be seen that, in the systems of Figures 1 and 2, the mixing chamber 6, in which the water mist is produced, is separate from and distanced from the outlets or spreaders 26,28. The spreaders 26,28 are not used for the formation of mist but simply for discharging the already formed mist. The systems thus contrast with systems using nozzles which combine a mixing chamber in which the mist is produced with outlets for discharging that mist into the area or enclosure to be protected. Advantageously, the mixing chamber 6 is at least one metre downstream of any flow regulators (e.g. 10,18) and upstream of the first T-junction (e.g. 23) or elbow.

The mist exiting the mixing unit 6 moves at high velocity and is entrained by and within the high pressure inert gas. The resultant turbulence in the pipe 22 helps to reduce the size of the droplets in the water mist. The high velocity water mist exits the spreaders as a two-phase mixture, consisting of the water droplets within the inert gas. The gas continues to expand, on exiting the spreaders 26,28, producing an even mixture. Fine water droplets are suspended within the gas throughout the discharge.

The conditions which produce turbulent flow in the pipe 22 will vary with pipe dimensions, nature of the gas, gas velocities and pressures and gas properties. These conditions can best be described in terms of the Reynold's number, Re. In general for turbulent flow, Re $>^{\sim}$ 2300. It is considered that in practice Re should be greater than 4000 and advantageously greater than 12000 at all points in the pipe network. From calculations carried out on the velocity and Reynold's number for enhanced mist production, it is believed that the maximum turbulence level and pressures will occur at or very close to the mixing chamber (or eductor). Beyond this point, pressure losses occur within the pipe 22 and hence turbulence levels will drop. Therefore, the greatest potential for producing fine water droplets will occur within or close to the mixing chamber. However, owing to the turbulent nature within the pipe, it is likely that water droplets will continue to impact against each other within the gas flow and continue to strip (reduce in droplet size). As the flow and turbulence levels within the pipe begin to fall, some larger water droplets begin to drop out of suspension. The difference in Reynold's number (turbulence) between the mixing chamber and the outlet spreaders will

determine how much water falls out of suspension. Only the fine droplets that remain suspended in the flow will exit the system and disperse. The water that falls out of suspension will either remain within the pipe network or exit through the outlet spreader as very coarse water droplets. These larger droplets will not aid fire suppression.

The spreaders 26,28 do not have any significant effect on the two-phase mixture. The function of the spreaders is

(a) to ensure homogeneity of distribution of the combined mist and inert gas within the protected volume;

(b) to ensure that the correct amount of suppressant (the combined mist and inert gas) enters each part of the protected volume, by varying the distribution of the spreaders;

(c) to ensure the correct discharge time, typically about 60 seconds.

As the suppressant leaves the spreaders, the cloud of water mist and inert gas continues to expand and forms an even distribution within the protected volume. The water mist remains suspended within the inert gas during the discharge. Because the liquid droplets are so small, they remain suspended for a significant period of time following the discharge. Therefore, a total flooding effect can be achieved for as long as the water

droplets remain suspended - which can be for several minutes.

The systems described have considerable advantages over fire extinguishing systems based on the use of inert gases alone. Fire extinguishing systems based on the use of inert gases on their own are well known but are not greatly favoured, in spite of having substantially zero ozone depletion potential (ODP) and zero global warming potential (GWP). In order to act efficiently for fire extinguishing purposes, inert gases must be used in relatively high concentration, in the range of 27 - 38 vol%. Large quantities of the inert gases therefore have to be stored. Because the inert gas has to be stored under relatively high pressure, storage cylinders are heavy. Such a system can therefore require increased floor space and increased floor loading capabilities.

A further disadvantage of fire extinguishing systems relying solely on inert gas is that the relatively high concentration of the inert gas which is required, to achieve efficient extinguishing action, necessarily reduces the oxygen concentration in the protected volume significantly. Thus, oxygen concentrations in the protected enclosure may be reduced to between 11 to 14 vol%. This obviously has implications for human survivability in the protected enclosure. Reduced oxygen concentration within this range may be survivable in the short term but is at least potentially unsatisfactory.

This problem is overcome in the systems described with reference to Figures 1 and 2 because the water mist added to the inert gas provides significantly increased fire

suppression performance and this in turn significantly reduces the amount of inert gas needed. Not only is there a consequent reduction in the space and weight requirements, but, because the inert gas concentration is lower, oxygen concentration within the protected enclosure is higher and there is less oxygen depletion risk to persons present in the enclosure. Clearly, water has no adverse ODP or GWP effects and therefore has no adverse environmental effect.

The addition of the water mist to the inert gas essentially enhances the fire suppression capability by raising the overall heat capacity of the atmosphere in the protected volume to such a level that combustion can no longer be sustained. In flame-type combustion, the reactions taking place necessarily involve high energy species such as free radicals, requiring the existence of high temperature - for example, 1,500 - 1,700 K, below which the reactions will not proceed and the combustion is thus not sustained. In other words, a large proportion of the energy released by the combustion process has to be used to heat up the air to flame temperature. If the heat capacity of the atmosphere within the protected enclosure is increased sufficiently (for example, up to 190 - 210 J/K/mol of oxygen), combustion cannot be sustained. The added water mist behaves in exactly the same way as the inert gas: it contributes heat capacity but does not otherwise become involved with the chemistry of the flame.

Because of the very small size of the water droplets, they require a much shorter residence time in the flame than systems employing larger water droplets, before fully evaporating.

When water droplets evaporate, the combined heat capacities of water in its liquid, latent and vapour phases all combine to produce a more effective suppressant.

In a modification, a suitable chemical agent is added to the water to improve the extinguishing and suppressing action. A suitable chemical agent is potassium hydrogen carbonate ($KHCO_3$). The presence of this chemical agent in the final mist increases the efficiency of fire suppression very significantly.

It is also important to note that the systems described preserve the total flooding capability of purely gaseous fire extinguishing systems. Because the water mist is added to the high pressure inert gas and then transported under high pressure and at high velocity along the pipe 22 (see Figures 1 and 2), the water is maintained in mist form with no significant loss of the mist through coalescence, and in fact the droplet size may be reduced further during transport down the pipe. Upon discharge into the area to be protected, the mist within the inert gas has very effective total flooding capability.

The reduced oxygen depletion produced by adding water mist to the inert gas in the manner described is illustrated more clearly in Figure 3 which shows results of tests carried out to establish the amount of oxygen depletion required to extinguish a class B fire under specific test conditions. The fire was a n-heptane fire within a one cubic metre test chamber and was required to be extinguished within one minute. The lefthand

vertical axis plots oxygen concentration (vol %) and the horizontal axis plots the amount of water mist present (flow rate of water in litres per minute). The inert gas used is nitrogen.

When there is no water mist present, the diamond-shaped plot A shows that the oxygen concentration needs to be reduced to about 15 vol% to achieve complete fire extinction. Taking into account the normal safety factor which would be required to be employed in a fire extinguishing system based solely on inert gas, the system would be required to have capability of reducing the oxygen concentration to 13.3 vol%. It is thus clear that this is quite close to the lower limit at which human survivability begins to be compromised (and at which particularly vulnerable people could be at significant risk). The square plots B show how the addition of water mist at various concentrations enable the fire to be extinguished at significantly higher levels of oxygen concentration. For example, when the water mist is present at a flow rate of about 1.5 litres per minute, the fire is completely extinguished at an oxygen concentration of just under 18%. Again, taking safety factors into account, such a system would need to be designed to reduce oxygen concentration to lie within the range between 15.3 and 16.5 vol% - where the risk to human survivability is very much less.

The triangular-shaped plots C in Figure 3 show oxygen concentrations which are required in order to provide complete fire extinction when a chemical agent (such as $KHCO_3$) is added to the water mist. It is clear that the required oxygen depletion is even lower.

In order to test the operation of a system similar to that shown in Figure 1 (but having a single spreader outlet), experiments were carried out in a $1m^3$ test chamber. Eight 50mm diameter and 50mm deep panfires were filled with water and n-heptane, and placed on shelves or stands which were evenly distributed within the test chamber. Each fire was partially baffled, which helped to reduce the effects of flame stretching caused by the flow of suppressant into the chamber. The spreader was screwed inside the chamber, at the centre of its top.

All eight fires were ignited and allowed to burn for 30 seconds. The test chamber was then closed. After a total of 50 seconds, nitrogen alone was discharged into the chamber by the system for a predetermined time.

The flow of nitrogen was adjusted until the fires had been extinguished. When the minimum extinguishing concentration for nitrogen had been achieved for the chamber, the experiments were repeated adding known flows of water to the flow of nitrogen. The resultant enhanced water mist provided better extinguishing properties and a new minimum extinguishing concentration was established. Further fire tests were carried out using water and potassium bicarbonate solution as the added suppressant to the flow of nitrogen. As before, minimum extinguishing concentrations were established.

After the fire testing had been completed, analysis was carried out on the water droplet sizes produced by the enhanced water mist generation system.

The results of the experiments can be summarised as follows:

The minimum extinguishing concentration for nitrogen (baseline tests) using the above apparatus and a flow rate of 800 L/min, was 29%.

The minimum extinguishing concentration for nitrogen and enhanced water mist was 16 vol%. This was achieved when 0.87 L/min of water was added to 800 L/min of nitrogen. The results show that enhanced water mist requires 45% less nitrogen to suppress the same fires when compared to the nitrogen baseline results.

The minimum extinguishing concentration for nitrogen and chemically enhanced water mist was 8.5%. This was achieved when 1.2 L/min of potassium bicarbonate solution was added to 800 L/min of nitrogen. These results show that enhanced chemical water mist requires 70% less nitrogen to suppress the same fires when compared to the nitrogen baseline results.

The average water droplet sizes that produced the most effective results in the fire test programme were $D_{v=0.1} = 6.3$ µm, $D_{v=0.5} = 26.3$ µm, and $D_{v=0.9} = 78.5$ µm (where $D_{v=0.5}$ is the mean droplet size, 10% of the droplets have a diameter below $D_{v=0.1}$, and 90% of the droplets have a diameter below $D_{v=0.9}$).

Some of the test results showing minimum extinguishing concentrations are illustrated

in Figure 4.

The systems described can also provide fire extinguishing and suppression capabilities existing over much longer periods of time. For example, a system purely using inert gas on its own is required to discharge in less than 60 seconds. A water mist system, on the other hand, can operate for several minutes or even hours depending on the system.

Water mist fire extinguishing systems are of course known in which an inert gas under pressure and water under pressure are arranged to impinge mutually to cause a shearing action on the water and thus the production of a water mist, this water mist then being propelled towards a fire to be extinguished by the pressurised inert gas. In such systems, however, the fire extinguishing medium consists substantially only of the water mist, except near the end of the discharge when most of the water has been deployed, when a stream of the inert gas may then have some fire suppression effect. In such systems, the water mist is discharged in jet-like form towards the fire, and cannot therefore provide a total flooding capability.

In this specification and its claims, the term "water" includes acqueous solutions or suspensions primarily comprising water but possibly also including other substances.

CLAIMS

1. A fire and explosion suppression system, comprising a source of water and a source of pressurised inert gas, water mist producing means connected to receive the water to produce a mist therefrom, mixing means for mixing the already-produced mist into a flow of the pressurised inert gas from the source thereof to produce a two-phase mixture comprising a suspension of droplets of the water mist in the pressurised inert gas, and transporting means for transporting the two-phase mixture to separate discharge means.

2. A system according to claim 1, in which the median droplet size of the water mist lies between 5 and 60 micrometres.

3. A system according to claim 1 or 2, in which the discharge means comprises at least one outlet and in which the transporting means comprises narrow pipe means interconnecting the entraining means with the outlet.

4. A system according to claim 3, in which the Reynold's number effective in the pipe means is at least 4000.

5. A system according to claim 4, in which the Reynold's number is at least 12,000.

6. A system according to any preceding claim, in which the water mist producing means and the source of the inert gas are connected to the mixing means by pipe means and the mixing means is at least one metre downstream of any flow restrictor in this pipe means.

7. A system according to any preceding claim, in which the water is mixed with a chemical fire suppressant carried by the mist.

8. A system according to claim 6, in which the chemical fire suppressant is potassium hydrogen carbonate.

9. A system according to any preceding claim, in which the pressurised gas is nitrogen.

10. A system according to any one of claims 1 to 8, in which the pressurised gas is argon.

11. A system according to any one of claims 1 to 8, in which the pressurised gas is a nitrogen and argon mixture.

12. A system according to any preceding claim, in which the water mist producing means comprises a nozzle.

13. A system according to any one of claims 1 to 11, in which the water mist producing means comprises an eductor.

14. Apparatus for producing a mist from a liquid, comprising an eductor.

15. Apparatus according to claim 14, including means connected to supply the liquid to the eductor and means connected to supply a gas to the eductor, the gas causing a reduction of ambient pressure in the eductor which draws the liquid into the eductor.

16. Apparatus according to claim 14 or 15, in which the liquid is water.

17. A fire and explosion suppression method, comprising the steps of producing a water mist from pressurised water, mixing the already-produced mist into a flow of pressurised inert gas to produce a two-phase mixture comprising a suspension of droplets of the water mist in the pressurised inert gas, and transporting the two-phase mixture for separate discharge.

18. A method according to claim 17, in which the median droplet size of the water mist lies between 5 and 60 micrometres.

19. A method according to claim 17 or 18, in which the water mist is entrained and transported while being longitudinally and cross-sectionally confined.

20. A method according to claim 19, in which the water mist is entrained and transported in conditions in which the effective Reynold's number is at least 4000.

21. A method according to claim 19, in which the Reynold's number is at least 12000.

22. A method according to any one of claims 17 to 21, in which a chemical fire suppressant is carried by the mist.

23. A method according to claim 22, in which the chemical fire suppressant is potassium hydrogen carbonate.

24. A method according to any one of claims 17 to 23, in which the pressurised gas is nitrogen.

25. A method according to any one of claims 17 to 23, in which the pressurised gas is argon.

26. A method according to any one of claims 17 to 23, in which the pressurised gas is a nitrogen and argon mixture.

27. A method of producing a mist from a liquid, in which a gas is fed under pressure to an eductor to draw the liquid into the eductor to produce the mist.

The Patent Office

19

INVESTOR IN PEOPLE

Application No:	GB 0123146.3	**Examiner:**	Colin Thompson
Claims searched:	1 to 13, 17 to 26, 28 to 32	**Date of search:**	1 February 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): A5A

Int Cl (Ed.7): A62C 5/00, 35/02, 39/00

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 0123146.3
Claims searched: 14-16, 27

Examiner: Colin Thompson
Date of search: 9 May 2002

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): A5A

Int Cl (Ed.7): A62C

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0784998 A2	(Morton International Inc) See Fig 2	14-16,27
X	WO 96/34660 A1	(Haro) See whole document	14-16,27
X	US 4634050 A	(Shippee) See Fig 1	14,16
X	US 4397422 A	(Gwyn) See Fig 1	14,15,27
X	US 4186772 A	(Handleman) See Fig 2	14-16,27

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		